Climate change and food security in Africa

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1.0 Introduction

The Intergovernmental Panel on Climate Change (IPCC) fourth assessment report (AR4), states that global temperature over the period of 100 years ending 2005 clearly shows an average global increase of 0.74 °C with the second half of the century being twice as warm as the entire period (IPCC, 2007). While global temperature projections are consistent over time, rainfall varies temporally and spatially, although there has been an increase in the parts of the world that are continuously being affected by excessive and insufficient rainfall (Porter and Semenov, 2005). These changes are projected to continue into the future, with implications for food crop producing areas and crop development.

The current paper is a synthesis of research undertaken by recipients of ACCFP fellowship awards. Each researcher investigated various aspects of food crop production and farmer/fisher responses to climate change in Cameroon, Mali, Morocco, Tanzania and southern Africa. The paper begins with an overview of climate change projections for Africa, and elements of food security. It looks at the projected impacts of climate change on food security, and then analyses farmer responses, and barriers to adaptation, before concluding with some recommendations.

2.0 Climate projections in Africa

There is now widespread agreement by most scientists and climate change professionals that climate change and increased climate variability are already occurring and having serious consequences for many African countries (Sallema and Mtui, 2008; URT, 2007a; Agrawala et al., 2003; Mwandosya et al., 1998).

All 21 General Circulation Models (GCMs) in the IPCC AR4 agree on warming across the continent (IPCC, 2007). Mean temperature projections range from increases of 1.8°C to 4.0°C, according to the different CO_2 emission scenarios defined in the special report on emission scenarios (SRES). However, the degree of warming projected varies from one region to the other across Africa. Higher mean temperatures are projected for the Sahel compared to other regions. Projections of future rainfall are more uncertain. Climate models do not agree on the magnitude or direction of rainfall changes. Mean annual rainfall is projected to increase in West Africa (+2%) and East Africa (+7%) and is projected to decrease in Sahel (−6%) and southern Africa (−4%). Marked variations are projected within seasons. These variations are significant for future crop production and food security.

3.0 Food security

Food security exists when all people at all times have physical or economic access to sufficient safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (FAO, 1996). At the household level, food security is measured by actual dietary intake of all household members using household income and expenditure surveys (FAO, 2002). Three components of food security are evident in this commonly used definition: availability, access, and utilization, all of which are climate sensitive. Another dimension of food security is the stability of the food system.

Availability relates to the production of food, in terms of its physical presence in a region. Crop productivity and food stocks, for example, relate to food availability. Access is characterized by the ability of an individual or household to obtain food. This depends on food prices, market accessibility, employment, and distribution of wealth (Verdin et al., 2005). Utilization is the ability of humans to derive full biological benefits from food, based on nutritional value, socio-cultural value, and food safety (Gregory et al., 2005).

t is believed that climate change will impact all four dimensions of food security namely: food availability, food accessibility, food utilization and food systems stability (FAO, 2008; Lobell et al., 2008). The impacts on food security will be both short term, resulting from more frequent and more intense extreme weather events, and long term, caused by changing temperatures and precipitation patterns. People who are already vulnerable to climate change and who are food insecure are likely to be the first affected due to inadequate adaptive capacities to deal with future climate change impacts. This paper focuses mainly on the food availability and accessibility aspects of food security.

4.0 The impact of climate variability and change on agriculture and food security in Africa

Agriculture in African countries is already under stress due to increases in population, industrialization and urbanization, competition over resource use and degradation of resources. The case study in eastern Cameroon also highlighted how the environmental consequences of gold mining affect the soil and water resources with implications for farming potential. The impacts of climate change will add more stress to agriculture.

In developing countries 70% of people in rural areas live off agricultural products and the livelihoods of roughly 450 million of the world's poorest people are entirely dependent on managed ecosystems services (FAO, 2004). The impacts of climate change for agriculture and food security in developing countries are of major concern because of marginal climatic conditions in many parts of Africa, subsistence

livelihoods, and limited resources for adaptation (Channing et al., 2011; Lyimo and Kangalawe, 2010; Ludi, 2009). Typically there is significant focus on the poor, agriculture-based countries in sub-Saharan Africa, but with 5% of its population already undernourished (FAO, 2010a), and demand outstripping climate-dependent production, North African countries such as Morocco are not exempt.

The relationship between climate change and food security is complex and dynamic. Climate related crop failures, fishery collapse and livestock deaths already cause economic losses and undermine food security, moreover, these are likely to become more severe as global warming continues (Nelson et al., 2009). It is widely accepted that climate change is already having dramatic effects on natural resources and is likely to affect food security by influencing livelihood productivity and opportunities (Kangalawe, 2012; Lyimo and Kangalawe, 2010; Kangalawe et al., 2008; Yanda et al., 2006; Mendelsohn and Dinah, 2005). Cropping systems can be more affected compared to livestock production system when climate variability occurs at a critical stage of growth (Midgley et al., 2012).

For the most part, impacts will be negative whereby erratic weather will undermine rain-fed agricultural systems; heat stress on crops will reduce yields and increases in carbon dioxide concentrations will decrease the protein content of vegetation, with implications for human and livestock health and productivity (Mendelsohn and Dinah, 2005). Interannual variability in precipitation has important consequences on ecosystems functioning and may have predictable impacts on plant's net primary production (NPP) and crop yields. In many regions of sub-Saharan Africa, inadequate soil moisture and low soil fertility have been top challenges facing rain-fed agriculture (Makurira et al., 2007). In the middle and high latitudes, increases in temperature and precipitation associated with an increase in atmospheric CO2 concentration may have some beneficial impacts on plant growth (Tagesson et al., 2012; Bounoua, 2004) while in arid and semi-arid regions, even small temperature increases may have

negative impacts (Easterling et al., 2007). Crop production levels are ultimately the result of the interplay between temperature, water availability, and carbon availability. Box 1 further highlights the circumstances where carbon fertilisation offsets the potentially negative effects of temperature and rainfall. If existing climate trends continue in the future, they may alter local food production (e.g. Droogers and Aerts, 2005; Droogers, 2004; Rosenzweig and Parry, 1994). The net decline in food production may also increase food prices, and consequently affect food affordability and security (Ringler et al., 2010). End consumers will feel the effects of food supply shortages and price shocks, as it occurred in the East Asian rice crisis in 2008 (Balfour, 2008), and Russia grain crisis in 2010. Thus, climate change is seen as another challenge to Africa reaching its potential food security. This provides the drive to push for the adaptation strategies that will enhance food insecurity in a changing climate (Kangalawe, 2012; Ringler et al., 2010; URT, 2008a).

“Cropping systems can be more affected compared to livestock production systems when climate variability occurs at a critical stage of growth.”

Box 1: Positive impacts of climate change

The impact of climate change on agriculture is not always negative. Rising CO2 levels have been found to be the driving force behind global warming and climate change. However, depending on crop physiology, increasing CO2 levels in the atmosphere can also increase crop yields through CO2 fertilisation (IPCC, 2007). Knox et al. (2010) noted that CO2 fertilisation offset the impacts of climate change and led to higher yields in Swaziland. Projected sugarcane yields increased by 15% with doubling CO2 levels by 2050.

Walker and Schulze (2006) found that doubling CO2 levels increased maize yields in Potshini, South Africa. They concluded that with a doubling in CO2 levels, the potential positive and negative drivers of maize yield changes would be self-cancelling, leading to maize yield increase thereafter. Abraha and Savage (2006) noted that given non-limiting conditions of water, the effect of CO2 was such that maize yields increased with doubling CO2 and 2°C temperature rise. However when temperature rises by 4°C, the positive effect of CO2 fertilisation is offset. Liu et al. (2008) partly attribute the projected overall increase in crop yields (1.6 – 3.3%) to CO2 fertilisation in the early 21st century.

Contrary to other studies, Parry et al. (2004) concluded that the effect of rising CO2 levels in the region is unable to counteract the projected cereal yield decline. Maize yields still fall by 30% despite the rising CO2 levels under the A1FI climate scenario. Chipanshi et al. (2003) concluded that the positive effects of rising CO2 levels are unlikely to be realised on maize and sorghum in Botswana. Statistical crop response projections made by Lobell et al. (2008) and Schlenkler and Lobell (2010) do not consider the effect of CO2.

As well as at the macro level, the impacts of climate change on food production can be considered at a sub-regional level. Southern Africa is a predominantly semi-arid region with high rainfall variability. It is known as one of the most vulnerable regions to climate change with a low adaptive capacity (especially in rural smallholder communities) combined with high dependence on rainfed agriculture (IPCC, 2007).

Although model projections of rainfall are uncertain, giving results of both increasing and decreasing rainfall, all models agree that temperature will increase over southern Africa. Temperature is projected to increase on average by 1.8 °C to 2.4 °C with a range of 1.3 °C to 2.7 °C across all sites and scenarios. In southern Africa, projected climates have potentially negative implications for crop production and livelihoods. Major crop production systems which support most of the livelihoods in southern Africa are located in the dry sub-humid and semi-arid zones.

“ Over 60% of the region’s livelihoods are agriculture and natural resource dependent and under 90% of all food production is under rainfed conditions.”

Most households in rural farming communities in southern Africa produce their own staple food (maize). However, crop yields in the region are highly sensitive to variations in climate (Porter and Semenov, 2005). Climate change is expected to exert even more pressure on future crop production systems (Challinor et al., 2007). Agriculture in the region has been found to be very prone to climate change and smallholder farming communities within the region are the most vulnerable (Ziervogel et al., 2008). Over 60% of the region’s livelihoods are agriculture and natural resource dependent and about 90% of all food crop production is under rainfed conditions (Cooper et al., 2008).

Box 2 reviews different methodologies and their projections for the impact of climate change on crop production in southern Africa.

Box 2: Different methodologies and their projections for the impact of climate change on crop production in southern Africa

The last decade has seen a substantial body of work on climate change impacts on crops whose results vary considerably across regions and within southern Africa (Roudier et al., 2011; Nelson et al., 2010; Thornton et al., 2009; Lobell et al., 2008; Jain, 2007; Walker and Schulze, 2006; Parry et al., 2004; Jones and Thornton, 2003; Rosenzweig and Iglesias, 2003). These studies suggest that the production of major crops is under threat from climate change and that efforts to adapt food crop production systems to climate change should be explored in order to promote future food security.

Impact studies in southern Africa produce different results based on applied methodologies, tools and location of the study within the region. While these studies are useful individually, a collective assessment would allow consistent information to be extracted. It would increase confidence in study results, especially towards adaptation planning. A study reviewed and consolidated 19 climate change impact studies on crop production in southern Africa over a decade (2001–2011). The review combined results from studies across several methods and tools of projecting crop response to future climate. These results suggest that aggregate impacts of climate change on crops in southern Africa will be negative

A comparison of projected crop response to future climate for southern Africa using process-based and statistical-based methods shows that even though the two methods are different in nature, they all predict a median decline in southern Africa crop yields (process-based: −11%; statistical based:− 19%) under climate change for all projected future time periods combined. The process-based method, however, has a much larger range of crop yield changes (−68% to 27%) than the statistical method. The combined crop yield response projections for the process-based and statistical methods indicates that a decline in crop yields is projected to increase with time. Projected median changes are 0% for the early 21st century, −18% for mid-21st century and −30% for late 21st century. The range of projections for the early 21st century shows almost equal projections of yield increase as yield declines. However, projected percentage crop yield changes for mid and late 21st century consistently show decline.

Another approach – the Ricardian approach – is commonly used for studying the impact of climate change on crop production in southern Africa. In this approach, different units of measurement i.e. monetary as opposed to the production (yield/ha) applied by other approaches, are used. Some Ricardian studies reviewed used uniform future climate scenarios by varying temperature and rainfall by constant amounts e.g. +1 °C or +10% increase in rainfall (Gbetibouo and Hassan, 2005; Mano and Nhemachena, 2006; Jain, 2007). The general trend for projections made using uniform climate scenarios is a decline in farm net revenues across all farm types and dry land farms in southern Africa (12% for dry land farms and 14% for all farm types). The range of projections for dry land farms is negative while that of all farms combined ranges from negative to positive change in revenue. The percentage of farm revenue from the Ricardian approach based on GCM scenarios was ordinarily more variables compared to the uniform scenarios of temperature and rainfall but the median change in farm net revenue is negative for all climate projections and farm types.

Research results show that the impacts of climate change on maize yields in southern Africa vary from one place to the other (Zinyengere et al., 2013). In the Lilongwe region of Malawi the impacts are projected to be mostly negative - projections show mostly a decline in mean maize yields between the baseline and future period for most climate scenarios, all CO2 emission scenarios and all management treatments.

However, there are also some projections of possible increase in mean maize yields for the area. Projected mean maize yield changes range from -11.3 % to 2.9 %. This is concerning for food security in Malawi since maize is the staple crop in the country and Lilongwe lies within the better performing mid-altitude region of Malawi which is the most suitable for maize production, receiving good seasonal rainfall. Lilongwe district also falls within a region which is perennially known to account for a large portion of Malawi's cereal production. Even a marginal reduction in maize yields can have a severe impact on household food security among poor farming communities. It is therefore important that the smallholder farming communities in Lilongwe adopt appropriate adaptation strategies.

The same research indicates that the impacts of climate change on maize yields are projected to be more severe for Big Bend in the Lowveld of Swaziland, a region of perennially low and highly variable rainfall and considered to be more suitable to growing small grains rather than maize. Despite the highly varying climate scenarios, projected mean maize yield changes for Big Bend are all negative. This strongly suggests that smallholder farmers in Swaziland may experience even more poor maize yields in the future as a result of climate change. Projections for Big Bend, Swaziland, show unanimously a decline in mean maize yields between the baseline and future period for all scenarios, ranging from -6 % to -43.8 %.

Results of the research show that the impact of climate change on maize production in Mohale's Hoek, Lesotho is uncertain. Simulations project both an increase and decrease in mean maize yields under future climate. Mohale's Hoek may benefit from a warmer future climate thereby experiencing higher maize yields than previously attainable. Lesotho commonly experiences a cold climate which is not conducive for maize production. However, climate change is projected to lead to higher future daily minimum temperatures in Lesotho. This may reduce the incidence of cold related crop failure and yield reduction thereby leading to increased maize yields. However, there are also projections for a decrease in mean maize yields.

These projections are common mainly under practices of low fertiliser application, common in smallholder systems in Lesotho, especially with early planting. This suggests that common smallholder management strategies will not be suitable under a changed climate and therefore farmers in Lesotho will need to adapt accordingly. There is high uncertainty in the projections for Lesotho about the direction of change in mean maize yields as a result of climate change - projected mean maize yields changes for Lesotho range from -60.4 % to 120%. Broadly speaking, Lesotho is one of very few southern African locations where potential yield increases are possible under climate change.

Modelled impacts at the macro scale are mirrored in high resolution qualitative-based case study information. In the Simiyu catchment of the Lake Victoria basin in Tanzania households are experiencing food shortage due to changing weather conditions. This was attributed to reduced rainfall, increased temperatures and increased incidences of drought which leads to crop failure and low yields. Furthermore, it was reported that livestock rearing in the catchment is reduced due to reduced availability of pastures.

“ Lesotho is one of the few southern African countries where potential yield increases; projected maize yields changes range from -60.4% to 120%.”

5.0 The impact of climate variability and change on fisheries and food security in Africa

As well as terrestrial agriculture, fisheries and aquaculture are important elements of food production that are also sensitive to climate change. As elaborated in recent studies (e.g. Makota et al., 2004; Shaghude, 2004), climate impacts on coastal communities, fisheries resources, recreation sites, tourist destinations and coastal infrastructures are already manifesting.

The fisheries sector in Tanzania, like elsewhere in the world, is vulnerable to climate change impacts as a result of rising sea surface temperatures that radically alter aquatic ecosystems and modify the distribution and productivity of fish species (see box 3 for the importance of fisheries in Tanzania). Catch declines and extinctions of commercially important fish species affect the livelihoods and food security of communities that depend on fisheries resources.

Coastal communities are among the poorest groups in Tanzania and fishing is often the primary, if not the exclusive, economic activity for making local livelihoods. For example, coastal communities in Bagamoyo have started to experience the impacts of climate change (Ngana et al., forthcoming; Mkama et al., 2013; Tobey et al., 2011; Coll Besa, 2010; Mushi, 2009). These impacts are anticipated to intensify in the future resulting in significant alteration of coastal and marine ecosystems as well as increased coastal hazards in low-lying areas. The experience has shown that the poorest communities are the most exposed to climate hazards and changes, yet they are least equipped to deal with the consequences.

Box 3: The importance of fisheries in Tanzania

Coastal communities in Tanzania have been depending on fishing activities for their livelihoods, income and protein for a long time. According to the Tanzanian National Fisheries Policy (1997), this sector contributed around 10% the GDP in the late 1990s (URT, 1997b).

This implies that the sector plays a significant role in promoting both social and national economic growth, enhancing local food security, and providing household cash income in Tanzania. Fish contribute about 30% of the total national animal protein intake to the Tanzanian population (URT, 1997) and fisheries are critical sources of food and income (TCMP, 2001), with an annual per capita consumption of about 10kg of fish. Over 90% of the marine fisheries catch is landed largely by artisanal fishers in coastal fishing communities (URT, 2007; Jiddawi and Öhman, 2002).

Research in the Bagamoyo district in Tanzania discovered that 48% of the respondents engage in fishing as their main source of income. When asked about the role of fishing activities in their food security, over 60% of the respondents said that fishing activities contribute greatly to food security. Furthermore, investigation revealed that fishing is the community's main source of income and contributes 68% of income to household's food security. Women were not directly involved in fishing activities but

fish processing (particularly frying) and selling, while others were food vendors. Fish was also reported to be their main source of protein served in the sold meals.

6.0 Farmers responses to climate change

The projected impacts of climate change mean that, in order to avoid adverse impacts on food production and security, adaptation will be required (Madisson, 2006). The types of adaptation that will be implemented depend on the farmers' perceptions of the changes in the climate. Research in terrestrial and coastal communities in Tanzania found that perceptions of change were largely matched by observational records. However, climate change is perceived differently depending on the level of education, livelihood activity, location and age (Mongi et al., 2010).

Adaptation measures range from large scale infrastructural changes to behavioural shifts and can be categorised into two types, namely reactive and anticipatory adaptation. While reactive adaptations are defined as those measures taken as a response to climate change, anticipatory adaptations are measures taken in advance of climate change so as to minimize or offset the effects of climate change.

Many agricultural adaptation options have been suggested in literature. They encompass a wide range of scales (local, regional, global), actors (farmers, firms, government), and types, this includes; micro-level options, such as crop diversification and altering the timing operations, market responses, such as income diversification and credit schemes, institutional changes, mainly government responses, such as removal of perverse subsidies and improvement in agricultural markets; and technological developments including the development and promotion of new crop varieties and advances in water management techniques (Kurukulasuriya and Rosenthal, 2003). A similar variety of adaptations were observed and/or required in the case studies. Table 1 summarises these adaptations and the locations in which they have been observed to be necessary.

Table 1: Different adaptation measures adopted in 5 African countries

Country	Morocco	Tanzania	Malawi	Lesotho	Zimbabwe
Adaptation					
Infrastructure to support transport	Y	Y	Y	Y	
Changing planting times		Y		Y	
Conservation agriculture	Y				
Planting modified varieties		Y			
Applying fertiliser		Y	Y	Y	Y
Diversification		Y	Y	Y	Y

The study in Morocco, North Africa, identified areas where adaptation strategies need to be emphasized. For example, improving on food production efficiency can increase the food supply. It is known that in high-income countries, as much as 30% of all food grown may be lost or wasted before and after it reaches the consumer (BSR, 2011) while in low-income countries, much waste occurs on the farm and in transportation of goods (Imhoff et al., 2004).

As such, investment in physical infrastructure to reduce losses during harvesting, transportation, processing and storage of goods is achievable, practical and of high priority.

In Tanzania, small holder farmers have developed several adaptation strategies including: timing of farm operations to coincide with changing rainfall regime; crop rotation; mulching the land to reduce the loss of moisture; planting drought tolerant varieties and early maturing seeds and the use of chemical fertilisers as well as organic manure. In some cases farmers have opted to diversify their livelihoods by engaging in non-agri-cultural income generating activities such as small businesses, charcoal making and carpentry so as to earn income for buying food for their households. Fishing communities in Tanzania have also started to diversify their activities by not depending only on fishing only but also doing other activities such as agriculture, salt making, livestock keeping and changing food preference behaviour.

Research in southern Africa has argued for the strategic use of crop management strategies as an adaptation option (Chipanshi et al., 2003; Jones and Thornton, 2003). The study showed that the use of appropriate fertiliser amount has strong benefits for maize production under a changing climate. The benefit of timing of planting dates was less certain for Malawi and Swaziland but apparent for Lesotho, where late planting could help exploit the benefits of a warmer climate in a perennially cold country. Other agronomic strategies include changing planting densities; crop variety changes; residue incorporation and tillage practices. Apart from on-farm agronomic management options, smallholder farmers in the region could adapt by diversifying their farming activities through better livestock and crop interaction. Reducing the reliance of livelihoods on rainfed crop production could cushion smallholder farming communities from unfavourable future climate and crop losses while also presenting them with better opportunities to readily exploit opportunities that may arise.

Other potential adaptation strategies include the development of irrigation technologies and using new and improved crop varieties (Lobell et al., 2008; Schlenkler and Lobell, 2010). The development and appropriate use of climate adapted crop varieties are frequently suggested adaptation options. Variety selection for drought resistance and heat tolerance is likely to reduce the negative impacts of a warmer future climate with variable rainfall. Jones and Thornton (2003) suggest that, given the history of cereal yield increases owing to crop breeding and technological development, moderate yield losses such as a 10% decline in maize yields could be compensated through the use of climate adapted varieties.

Diversification is also a strategy that could be useful to over 60% of smallholder farmers in southern Africa who rely on rainfed crop production and natural resources for food and livelihoods (Chipanshi et al., 2003; Jones and Thornton, 2003; Cooper et al., 2008; Ziervogel et al., 2008). Reducing the reliance of livelihoods on rainfed crop production could cushion smallholder communities from unfavourable future climate and crop losses. Increased access to markets as suggested by several

Lady carrying hay
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studies may help to improve on-farm profitability. Farmers would be able to save and to intensify farming, thereby increasing their capacity to cope with unfavourable impacts of climate change while also readily exploiting opportunities that may arise.

Most studies emphasise on-farm adaptation options, mainly through the adjustment of farm management strategies (planting dates, changing crop types, appropriate water and fertiliser management and irrigation). Since smallholder farmers in southern Africa have been known to historically cope with variations in climate through adjusting management strategies (Twomlow et al., 2008), such an option could be a natural choice for smallholder farming communities to adapt to future climate.

Suggested improvements in climate forecasting and dissemination of forecasts, complemented by enhanced access to extension services would better prepare farmers to make use of these management strategies especially given increased future rainfall variability. Farmers would be better able to use irrigation and in-field water harvesting timely and appropriately thereby reducing the negative impact of dry spells and exploiting the potential benefits of increased rainstorms.

Farmers would also be able to time planting and fertiliser application well, in so doing avoid crop losses resulting from insufficient moisture for germination at the beginning of the season and the leaching of nutrients. All suggested adaptation options will most likely include various stakeholders such as governments, private organisations, non-profit organisations and the farmers themselves. Climate change adaptation strategies should therefore be developed and recommended within the context of stakeholders and their different roles.

6.0 Constraints to adaptation

There are numerous barriers to adaptation. Research amongst farmers in the semi-arid region of Shinyanga, Tanzania, shows that perceived constraints to adaptation include hindrances to the adoption of modern techniques as adaptation strategies to climate change; lack of current knowledge on adaptation methods; lack of improved seeds, such that non-availability of the desired variety seed and higher price of improved seeds were significant hindering factors in cultivation of maize and cotton; lack of money to acquire modern techniques; lack of access to water for irrigation and lack of information on weather incidences. All these effects were obvious challenges to crop production in the study area, corroborating with the report of Mongi at al. (2010) that food security is an attendant consequence of climate variation in Tanzania.

In the Simiyu Catchment of Lake Victoria Basin in Tanzania it was revealed that smallholder farmers have limited capacity in adapting to climate change impacts in food production due to financial constraints; technological constraints; lack of education; few institutions with the capacity to deal with adaptation as well as widespread poverty in the catchment. In this regard, communities in Simiyu catchment are opting for other adaptation options such as buying foods; selling assets and reducing the number of meals but these are not sustainable for adapting to future climate change impacts on food security.

7.0 Recommendations

Future food security depends on investment decisions made today for addressing climate change and adaptation issues, conserving water resources, bioengineering new seeds, renewing investments in agricultural water supply and diversifying food production away from traditional farming (e.g. Hanjra and Qureshi, 2010). However, it is not enough to address just one side of the equation (the production of more food). Research in Morocco concludes that, in order to meet the challenge of reducing vulnerability and achieving food security in a changing climate, not only food production must undergo a transformation, but a more responsible consumption and use of modern technology must be put in place as well, to reduce the adverse effects of climate and population growth.

Studies into crop-breeding and phyto-sanitary conditions have highlighted recommendations for changes at the level of seed choices. An experimental model of cultivar characteristics for sorghum and millet as trialled in Mali showed that breeding should be seeking to simulate floral stimulation based on the projected conditions (particularly day length and temperature), with the ultimate aims that flowering occurs at the end of the rainy season to enable some flexibility in planting dates (Traoré et al., 2000). However, testing such new cultivars in the intended environmental conditions is essential to ensure their robustness before recommending for particular conditions. Modifications to seed and breeding for improved resilience of livestock under climate change conditions were also highlighted as a priority need in eastern Cameroon.

At the level of the farmer or fisher, support to improve existing response strategies is also required. Farmers in Shinyanga, Tanzania, had a number of recommendations for adaptation, including developing resistant crops to enhance adaptation to climate change; providing education to farmers; diversifying crops; creating a greater awareness about climate change; promoting the application of mulch and providing food crops. Other recommendations included the point that agricultural research should come up with techniques and technologies to reduce the effects of climate variation; and extension services should get abreast of proven adaptation strategies to climate variation and work them out with farmers.

Improved extension services was also a recommendation for improved adaptation among coastal fishing communities in Bagamoyo, Tanzania. So far, these fishers have taken a good step in adapting to climate change impacts. However their initiatives are low level hence the need to support them in terms of expertise and extension service is of priority. There also needs to enhance and provide technical assistance to indigenous adaptation options that can promote fisheries resource management hence improve the wellbeing of the entire community. Serious efforts to adaptation in collaboration with communities are vital. This will make fisheries sector continue to be an important source of local food security and contribution to the national economy.

Climate change responses requires many steps, however, identifying the policy options available to address the adverse effects of such change is among the first steps to be taken. This requires policymakers to aim at promoting adaptation strategies for agriculture that have the greatest co-benefits in terms of agricultural productivity, climate change mitigation, and sustainable development.

If adaptation measures only address one type of climate change, such as increased flooding due to wetter conditions, they might leave the sector vulnerable to another type of climate change, such as drought from drier conditions. To address the broad range of uncertainties, anticipatory adaptation policies should be flexible.

The objective in selecting an anticipatory adaptation policy should be to enhance the ability to meet stated objectives under a wide range of climatic conditions. As such, a policy may be either robust, meaning it allows the system to continue functioning under a wider range of conditions; or resilient, meaning it allows the system to quickly adapt to changed conditions. Policy options for adaptation to agriculture may include: developing new crop types and promoting seed banks. Also, governments can have a role in stimulating adaptation as an important policy response to climate change. If these adaptations occur, climate change may lead to much lower damages and even benefits in some circumstances and locations.

" If adaptation measures only address one type of climate change, such as increased flooding due to wetter conditions, they might leave the sector vulnerable to another type of climate change such as drought from drier conditions."

8.0 Conclusion

Climate change is already affecting crop production and levels of food security in Africa. This paper has synthesised empirical research undertaken by recipients of ACCFP fellowship awards. Each researcher investigated various aspects food crop production and farmer/fisher responses to climate change in Cameroon, Mali, Morocco, Tanzania and southern Africa.

The impacts of climate change on agriculture and fisheries in Africa is largely expected to be negative, based on increasing heat stress, more variable amounts and distribution of rainfall, and changes in carbon dioxide concentrations (although there are selected examples where carbon fertilisation will offset negative effects of temperature and rainfall change); as well as changes in fishery distributions due to change in sea level temperatures. Various responses have already been observed in response to observed climate change. These include changes to planting times, conservation agriculture, developing and planting modified seed varieties and cultivars, applying fertiliser, and diversification of livelihoods.

However, the nature of response strategies often depends on access to finance, technology, and technical known-how. Recommendations to improve food security in a context of climate change include developing appropriate technology (including seed types) and ensuring that techniques and knowledge are appropriately communicated to farmers and fishers, for example through extension services. Appropriate policies are necessary to enable this. measures

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